Interactions of Lime and Molybdate in the Nutrition of Centrosema Pubescens and Pueraria Phaseoloides

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Two pot culture experiments are reported, in which the effects of applications of lime and sodium molybdate on the growth and nutrient status of Centrosema pubescens and Pueraria phaseoloides were examined. With three sedentary soil types, uptake of molybdenum at a soil pH value of below 5 was sufficiently low to limit plant growth. Application of sodium molybdate at the rate of 1 lb per acre and/or liming the soil to pH 6, increased the molybdenum and nitrogen contents of the plants, and increased dry weight production. It is suggested that the beneficial effect of liming is mainly due to its effect on molybdenum uptake.

Leguminous creepers are used as cover plants in rubber cultivation and the possibility of their growth being limited because of minor element deficiencies in the soil has been discussed in a previous article (WATSON 1957). Molybdenum is one of the minor nutrient elements most likely to be available at only low levels in Malayan soils and there is an unconfirmed report of leguminous cover plants benefiting from the application of sodium molybdate (SANDISON AND HANLEY 1954). The great majority of Malayan soils are acid, with pH values ranging between 4.5 and 5.5, and under these conditions the molybdenum in the soil is held at a very low level of availability (DAVIES 1956). This effect is likely to be accentuated in lateritic soils where the molybdenum will also tend to be held, with iron oxide, in an unavailable form (PRESCOTT AND PENDLETON 1952; MULDER 1954) Molybdenum is of importance in the symbiotic nitrogen fixation process characteristic of legumes (ANDERSON AND THOMAS 1946; ANDERSON 1956), and the pot experiments reported here were carried out to determine to what extent the uptake of molybdenum of leguminous creepers can be affected by soil type and acidity.

EXPERIMENTAL METHOD

Two leguminous creepers commonly grown as cover plants, *Centrosema pubescens* and *Pueraria phaseoloides*, were used in two separate experiments. The experimental treatments were:

Soil Types

Experiment I *(Centrosema pubescens)*

1. Serdang Series, sandy loam
2. Rengam Series, sandy clay loam
3. Selangor Series, alluvial heavy clay

Experiment II *(Pueraria phaseoloides)*

1. Serdang Series, sandy loam
2. Rengam Series, sandy clay loam
3. Selangor Series, alluvial heavy clay
4. Malacca Series, loam

Soil pH Levels (Both Experiments)

1. As received from the field, below pH 5
2. pH 6.0
3. pH 7.0

Molybdate Levels (Both Experiments)

1. No application
2. Sodium molybdate applied at a rate equivalent to 1 lb per acre (0.013 g. $Na_2MoO_4 \cdot 2H_2O$ per pot)

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The treatments were applied in duplicate, giving a total of 36 pots for Experiment I and 48 pots for Experiment II.

The soil types used in the two experiments were obtained from the same sites but at different times and the two sets of bulk samples differed somewhat on analysis (Table 1). The results from the two experiments are however grouped together in the tables for convenience. The different pH levels were obtained by mixing slaked lime intimately into the soil in appropriate quantities determined from the lime-titration curves of the soils. Any appreciable decreases in the soil pH values occurring during the course of the experiments were corrected by adding suitable quantities of lime in water suspension.

Large clay pots, painted on the inside with bituminous paint, were filled with approximately 75 lb of soil and limed to the required pH levels. Where necessary, sodium molybdate was applied in solution. Application of fertiliser solution equivalent to dressings of 2 cwt per acre of superphosphate, and 1 cwt per acre each of muriate of potash and magnesium sulphate, were made to all pots in both experiments. No nitrogenous fertilisers were applied. The experimental plants were established from seed inoculated with effective rhizobia (Rubber Research Institute of Malaya 1954) and allowed to grow for some 4½ months, in which time several cuts of green material were taken. Analytical results from all samplings were similar and only those from the final sampling are discussed in this paper. At the final sampling all leaf and stem material was cut, and the roots and nodules were collected and washed free from soil. In Experiment I the *Centrosema pubescens* leaf and stem material was analysed as one sample, but in Experiment II the leaf and stem of the *pueraria phaseoloides* samples were analysed separately.

RESULTS

Dry Weight of Material Produced per Pot

The dry weight of leaf and stem produced in both experiments was significantly increased by liming the soil to pH 6, but growth decreased slightly on liming further to pH 7 (Table 2). The weight of nodules produced per pot generally decreased with increasing soil pH. In Experiment II the weight of roots produced also decreased with increasing soil pH, but calculation showed no consistent effect of pH on the weight of nodules produced per unit weight of root.

The weight of leaf, stem and nodules, varied significantly between the different soil types, the greatest quantities being produced in the Selangor Series clay. In Experiment I there was a tendency for more leaf and stem to be produced in the presence than in the absence of molybdate at the lowest pH level, and in Experiment II this effect was statistically significant for all soils except the Selangor Series clay. At the two higher pH levels, the application of molybdate had no significant effect on the weight of plant material produced.

Calcium Content

The calcium content of the leaf, stem and nodules of both plants was increased appreciably by liming to pH 6, with a smaller increase following further liming to pH 7 (Table 3); this effect was more marked with the three sedentary soils than with the alluvial clay. The application of molybdate had no significant effect on the calcium content.

Molybdenum Content

Liming and the application of molybdate both had marked effects on the molybdenum content of leaf, stem and nodules (Table 4). A general linear response to the application of calcium was found, and high levels of molybdenum appeared at pH 7 in both with and without applied molybdate. The application of molybdate significantly increased the molybdenum content of the leaf, stem, and nodules of both plants at all pH levels, although with *Pueraria* the increases were smaller and less consistent in the leaf than in the stem and nodules. At the lowest pH level, and in the absence of applied molybdate, higher quantities of molybdenum were found in the leaf and nodules of the *Pueraria* than in its stem but, as uptake increased following application of molybdate and/or lime, the position was reversed, much higher levels being found in the stem.

Significant differences in molybdenum uptake by plants growing on the different soil types were recorded. In Experiment I, plants growing in the Rengam Series soil had the highest molybdenum content. In Experiment II, molybdenum uptake from the different soils was more even, but liming, in the absence of applied molybdate, gave a greater increase in molybdenum uptake on Selangor Series clay than on the other soils.

Nitrogen Content

In Experiment I, the nitrogen content of the *Centrosema* leaf, stem, and nodules, was significantly increased by the application of molybdate, and this effect was particularly marked at the lowest pH level; the nitrogen content was also increased by the application of lime (Table 5).

In Experiment II, the application of lime caused a significant increase in the nitrogen content of the leaf and tended to increase that of the nodules. In this experiment, the application of molybdate increased the nitrogen content of leaf, stem and nodules only in the absence of applied lime.

Manganese Content

The results in Table 6 show that the application of lime markedly decreased the leaf and stem content of manganese. In the absence of applied lime, the application of sodium molybdate significantly decreased the leaf and stem content of manganese. In the high pH treatments, only minor differences existed between the manganese contents of the leaf and stem of *Pueraria*, but when grown in soil at field pH, the stem contained much more manganese than did the leaf.

Magnesium, Potassium and Phosphorus Content

No marked treatment effects on the contents of magnesium, potassium and phosphorus were recorded. The application of these elements as fertilisers at the commencement of the experiment probably raised their level of availability in the soil sufficiently to mask any slight treatment effects. The results for magnesium are given in Table 7, since the relative importance of calcium and magnesium in legume and rhizobium nutrition is the subject of discussion (McCalla 1937; Norris 1959).

DISCUSSION

Effect of Soil Type

The soils chosen for the experiments were representative samples of the more important soil types used for rubber cultivation (Owen 1951). The nutrient status, as determined by soil analysis, was similar in each of the three sedentary soils, the Kedah, Rengam and Malacca Series soils, although the ferruginous nature of the Malacca Series loam was reflected in a low silica/sesquioxide ratio. The plants grown on these three soils gave similar responses to treatments. The Selangor Series alluvial clay is a fertile soil with a high nutrient status. Rubber growing on this soil will rarely respond to fertiliser application, and the leguminous creepers grew more vigorously and showed less response to the molybdate application when growing on this soil than on the other three. A surprising feature of plants grown on this soil, bearing in mind its high calcium status, was their more marked response in leaf and stem production to the application of lime. This difference may have been due to an effect of the lime application on the structure and aeration of this fine textured soil—a suggestion which is supported by the observation that the weight of roots in this soil was uniform through the pH range, but fell by 50% over the range pH < 5 to pH 7 in the other soils.

Higher manganese contents were found in plants growing in the Malacca Series soil than in those growing in the Selangor Series soil, although the latter contained a much higher level of exchangeable manganese. Definite conclusions cannot be drawn from the limited soil analytical data available (Table 1) but this effect may well be related to the much higher exchangeable calcium/exchangeable manganese ratio of the Selangor Series soil (KIPPS 1947; HEWITT 1948)).

The Selangor Series clay contained the highest level of total molybdenum, and in Experiment II higher levels of molybdenum were found in the roots and nodules in this soil, in all treatments, than in the other soils. The low response to molybdate application shown by plants growing in this soil is probably a reflection of its relatively high molybdenum status. In the case of the leaf and stem contents of molybdenum, this superiority of the alluvial clay soil was shown only at the two lower pH levels and in the absence of applied lime. The Selangor Series clay had the highest silica/sesquioxide ratio, while the Malacca Series had the lowest, but molybdenum uptake does not appear to have been related to this factor. A larger number of soils, with a range of silica/sesquioxide ratio values, would need to be used before a definite conclusion on this point could be drawn.

Effect of Lime and Molybdate Treatments

The major effects of the lime treatments on the plant nutrient status were marked increases in the calcium and molybdenum contents and sharp decreases in the manganese content of the leaf and stem; these particular responses were very marked but growth responses were not correspondingly high. The most important growth response, occurring in both experiments, was an increase in leaf and stem production caused by liming up to pH 6. With the three sedentary soils, further liming to pH 7 caused a slight decrease in dry weight production compared with that at pH 6, although at the same time the leaf molybdenum and calcium contents were further increased. The weight of nodules produced per pot generally decreased with increasing soil pH, and in Experiment II the weight of roots decreased also. If the nitrogen content of the increased amount of green material had been produced solely by increased nitrogen fixation it might have been thought that the efficiency of nodule activity had been increased, but liming will also have affected the mineralisation of the soil organic nitrogen (GUHA AND WATSON 1957) and so no definite conclusion can be reached on this point.

The application of molybdate to the soil increased the molybdenum content of all materials at all pH levels and decreased the manganese content at the lowest pH level. In both experiments the application of lime tended to increase the nitrogen content of leaf, stem and nodule material but the application of molybdate increased the nitrogen content at the lowest pH level only. At this pH level, where the plants contained only low levels of molybdenum, the nitrogen content of the leaf and nodule material from both experiments was significantly correlated with the molybdenum content, both in the presence ($r = 0.79$, significant at 0.01% level) and absence ($r = 0.80$, significant at 0.01% level) of applied molybdate. Molybdenum is known to play a particularly important role in the nitrogen metabolism of legumes, and this correlation suggests that at the lowest pH level the molybdenum content of the test plants was at a low enough level to limit nitrogen fixation. The molybdenum content of plants growing in the absence of applied lime or molybdate was very low indeed and application of molybdate to the soil increased both the molybdenum content and nitrogen content of the plants. Liming of the soil to pH 6 caused rather greater increases in both the molybdenum and nitrogen contents, while the application of both lime and molybdate gave a slight further increase on average. Liming to pH 7 increased the molybdenum content even further but gave no increase in nitrogen content, and molybdenum uptake at this pH level could well have been in excess of the plants' requirements.

Because of the effect of lime in increasing molybdenum uptake it is not possible from these experiments to determine the direct effect of the lime applications. Since there was a definite beneficial effect from the application of molybdate in the absence of liming, it seems possible that the benefit conferred by the application of lime at the first level was mainly due to its effect in increasing the availability of molybdenum in the soil. This would conform with the opinion that legumes indigenous to the humid tropics do not have a high calcium requirement (NORRIS 1956, 1959), and that reported benefits from liming (e.g. LANDRAU *et al.* 1953 SAMUELS and LANDRAU 1953) are more probably due to a release of other limiting nutrients within the soil than to a direct effect of the calcium. The beneficial effect of basic slag on the growth of *C. pubescens* reported by HAMILTON AND PILLAY (1941) may also, in a similar manner, have been due to an effect of basic slag on the minor element nutrition of the plants, as the authors suggested. NORRIS (1959) states that the root nodule bacteria associated with tropical legumes have a greater requirement for magnesium than for calcium. The magnesium status of the test plants was not affected by the lime or molybdate treatments in any general manner, and it must be presumed that this element was sufficiently available for the needs of both the plant and bacteria at all pH levels. The beneficial effect of the lime applications observed in these experiments cannot have been due to the depression of the high manganese uptake observed at the lowest pH level, for such an uptake of manganese is normal for the test plants in their natural environment, and in any case the application of molybdate at the lowest pH level increased the growth and nitrogen content of the plants while decreasing the manganese level to only a small extent.

It can be concluded that, under the conditions of this experiment, the uptake of molybdenum by *Pueraria phaseoloides* and *Centrosema pubescens* when growing in the sedentary Kedah Series, Rengam Series and Malacca Series soils at field pH level was at a growth-limiting level. An increase in available molybdenum in these soils, caused by application of either sodium molybdate or lime, increased both the molybdenum and nitrogen content of the plants and there was a tendency for increases in dry weight production to occur at the same time. The Selangor Series alluvial clay had a higher content of available molybdenum than the sedentary soils and uptake of the element at field pH was adequate for plant growth. The conclusion should not be drawn from these experiments that the normal leguminous cover will generally respond to applications of either lime or sodium molybdate. However, some indication is given of the availability of applied molybdate, should such an application be thought necessary in cases of suspected molybdenum deficiency. For experimental purposes the results show the importance of considering molybdenum uptake by the plant when carrying out liming trials with legumes.

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TABLE 1. SOIL ANALYSIS

Soil	Experiment	pH	Carbon %	Total nitrogen %	Exchangeable cations (m.equiv. per 100 g soil)			$\frac{SiO_2}{R_2O_3}$ (1)	Exch. Mn *p.p.m.*	Total Mo p.p.m. (2)
					Ca	Mg	K			
Kedah Series,	I	4.37	0.51	0.065	0.14	0.01	0.03	—	—	—
sandy loam	II	4.98	1.12	0.103	0.16	0.08	0.07	0.95	1.2	0.92
Rengam Series,	I	4.74	0.45	0.052	0.24	0.05	0.07	—	—	—
sandy clay loam	II	4.99	1.10	0.111	0.61	0.26	0.17	0.84	—	1.23
Selangor Series,	I	4.35	0.89	0.110	3.23	7.28	0.32	—	—	—
alluvial clay	II	4.70	1.66	0.195	2.02	1.94	0.48	1.37	11.1	3.84
Malacca Series,	I	—	—	—	—	—	—	—	—	—
loam	II	5.00	1.28	0.099	0.07	0.08	0.01	0.46	3.8	1.08

(1) Determined on ignited clay (2) Determined in 5:3 HCl soil extract

TABLE 2. DRY WEIGHTS OF MATERIAL PRODUCED IN GRAMS PER POT

Experiment	Material	Soil pH	Soil Series								Mean	s.e.
			Kedah		Rengam		Selangor		Malacca			
			Molybdate level									
			0	1	0	1	0	1	0	1		
I (*Centrosema pubescens*)	Leaf and stem (all samplings)	< 5	10.3	14.3	27.6	42.8	118.5	127.7			56.9	
		6	15.8	46.4	58.9	39.6	183.7	178.5			87.2	± 4.6368
		7	29.4	10.9	38.3	16.4	187.3	179.2			76.9	
		Mean	18.5	23.9	41.6	32.9	163.2	161.8				
		s.e.	± 6.5038									
	Nodules	< 5	1.34	1.06	2.63	2.29	2.66	3.86			2.31	
		6	1.25	1.94	3.49	2.30	2.35	2.28			2.27	± 0.277
		7	1.40	0.47	2.66	1.00	1.39	1.28			1.37	
		Mean	1.33	1.16	2.93	1.86	2.13	2.47				
		s.e.	± 0.391									
II (*Pueraria phaseoloides*)	Leaf and stem (all samplings)	< 5	86.6	119.7	124.7	139.0	144.3	131.8	76.3	92.6	114.4	
		6	134.3	133.6	160.8	151.4	180.0	159.6	127.1	127.2	146.8	± 2.645
		7	103.5	128.2	115.3	121.0	202.7	209.5	114.7	112.8	138.5	
		Mean	108.1	127.2	133.6	137.1	175.7	167.0	106.0	110.9		
		s.e.	± 4.319									
	Roots	< 5	33.6	39.8	35.5	35.0	30.2	27.2	36.0	41.5	34.9	
		6	39.2	35.5	35.0	34.5	30.2	33.3	36.5	34.5	34.8	± 1.0656
		7	15.6	24.3	18.0	21.5	28.3	32.8	23.0	19.5	22.9	
		Mean	29.5	33.2	29.5	30.3	29.6	31.1	31.8	31.8		
		s.e.	± 1.7401									
	Nodules	< 5	4.04	4.12	6.24	4.80	4.49	3.83	5.26	3.58	4.55	
		6	4.41	2.63	4.13	4.82	3.58	4.63	2.46	3.23	3.74	± 0.2871
		7	2.36	4.31	3.12	1.99	5.09	6.12	2.38	2.40	3.47	
		Mean	3.60	3.69	4.50	3.87	4.39	4.86	3.37	3.07		
		s.e.	± 0.4688									

TABLE 3. PERCENTAGE CALCIUM IN LEAF, STEM AND NODULES

Experiment	Material	Soil pH	Soil Series: Kedah		Rengam		Selangor		Malacca		Mean	s.e.
		Molybdate level	0	1	0	1	0	1	0	1		
I (*Centrosema pubescens*)	Leaf and stem	< 5	0.17	0.13	0.20	0.25	0.35	0.26			0.23	
		6	1.50	1.27	1.67	1.65	1.18	1.20			1.41	± 0.043
		7	1.32	1.55	1.82	2.06	1.39	1.13			1.55	
		Mean	1.00	0.98	1.23	1.32	0.97	0.86				
		s.e.	± 0.0608									
II (*Pueraria phaseoloides*)	Leaf	< 5	0.28	0.25	0.51	0.43	0.33	0.32	0.25	0.18	0.32	
		6	1.46	1.58	1.24	1.18	1.07	1.09	1.21	1.07	1.24	± 0.0265
		7	1.64	1.75	1.47	1.52	1.29	1.20	1.72	1.60	1.52	
		Mean	1.13	1.19	1.07	1.04	0.90	0.87	1.06	0.95		
		s.e.	± 0.0433									
	Stem	< 5	0.38	0.32	0.68	0.54	0.40	0.38	0.28	0.23	0.40	
		6	1.86	1.99	1.53	1.61	1.42	1.42	1.55	1.47	1.61	± 0.0275
		7	2.69	2.43	2.18	2.37	1.62	1.51	2.18	2.07	2.13	
		Mean	1.64	1.58	1.46	1.51	1.15	1.10	1.34	1.26		
		s.e.	± 0.0449									
	Nodules	< 5	0.10	0.10	0.19	0.16	0.10	0.10	0.05	0.07	0.11	
		6	0.94	1.12	0.75	0.70	0.67	0.63	0.62	0.46	0.74	± 0.0368
		7	1.23	1.59	1.10	1.01	0.75	0.70	0.75	0.54	0.96	
		Mean	0.76	0.94	0.68	0.62	0.51	0.48	0.47	0.36		
		s.e.	± 0.0060									

TABLE 4. MOLYBDENUM IN LEAF, STEM AND NODULES, P.P.M.

Experiment	Material	Soil pH	Soil Series: Kedah, Molybdate level 0	Kedah 1	Rengam 0	Rengam 1	Selangor 0	Selangor 1	Malacca 0	Malacca 1	Mean	s.e.
I (*Centrosema pubescens*)	Leaf and stem	< 5	0.12	0.94	0.07	1.19	0.10	0.93			0.56	*
		6	3.03	11.74	3.30	37.96	1.34	15.92			12.22	
		7	1.30	17.04	4.29	89.37	2.24	15.84			21.68	
		Mean	1.48	9.91	2.55	42.84	1.23	10.90				
		s.e.			*							
	Nodules	< 5	0.40	4.96	0.74	4.17	2.02	3.70			2.67	± 0.6583
		6	9.47	13.19	3.93	15.38	3.32	6.25			8.59	
		7	5.54	16.87	7.20	31.40	6.54	10.51			13.01	
		Mean	5.14	11.67	3.96	16.98	3.96	6.82				
		s.e.			± 0.9382							
II (*Pueraria phaseoloides*)	Leaf	< 5	0.33	0.18	0.43	0.46	0.95	0.94	0.74	1.11	0.64	± 0.3789
		6	0.21	0.94	0.71	0.96	1.76	2.68	0.68	0.60	1.07	
		7	0.38	1.26	0.98	5.20	4.62	1.35	0.98	2.61	2.17	
		Mean	0.31	0.79	0.71	2.21	2.44	1.66	0.80	1.44		
		s.e.			± 0.6187							
	Stem	< 5	0.06	3.25	0.04	1.30	0.86	2.18	0.02	2.16	1.23	*
		6	0.10	9.56	0.69	6.78	4.27	8.61	0.15	2.46	4.08	
		7	2.29	15.65	8.00	27.96	19.95	26.71	6.05	31.43	17.26	
		Mean	0.82	9.49	2.91	12.01	8.36	12.50	2.07	12.02		
		s.e.			±							
	Nodules	< 5	0.33	2.48	0.73	1.31	2.72	3.28	0.16	0.77	1.47	± 0.1880
		6	0.67	2.48	0.64	1.93	5.65	5.23	0.81	1.69	2.39	
		7	1.60	4.26	2.47	4.17	10.60	10.54	1.54	2.94	4.77	
		Mean	0.87	3.07	1.28	2.47	6.32	6.35	0.84	1.80		
		s.e.			± 0.3069							
	Roots	< 5	0.03	0.91	0.08	0.83	0.30	1.52	0.02	0.11	0.48	
		6	0.03	0.95	0.14	1.09	0.69	2.37	0.01	0.28	0.70	
		7	0.13	1.02	0.28	3.79	1.87	8.04	0.14	0.51	1.97	
		Mean	0.06	0.96	0.17	1.90	0.95	3.98	0.06	0.30		
		s.e.			*							

* s.e. not calculated because of large variation in treatment means.

TABLE 5. PERCENTAGE NITROGEN IN LEAF, STEM AND NODULES.

Experiment	Material	Soil pH	Kedah 0	Kedah 1	Rengam 0	Rengam 1	Selangor 0	Selangor 1	Malacca 0	Malacca 1	Mean	s.e.
I (*Centrosema pubescens*)	Leaf and stem	< 5	2.15	3.25	2.60	3.08	2.74	2.88			2.78	± 0.067
		6	3.23	3.27	2.88	2.87	2.76	2.84			2.98	
		7	3 00	3.61	2.66	2.35	2.77	2.78			2 86	
		Mean	2 79	3.38	2.71	2.77	2.76	2.83				
		s.e.	± 0.0946									
	Nodules	< 5	3.30	4.65	3.57	4.26	4.77	5.30			4.31	± 0.0707
		6	4.35	4.48	4.06	4.12	4.65	5.01			4.45	
		7	4.24	4.85	4 35	3.98	4.92	5.02			4.56	
		Mean	3.96	4.66	3.99	4.12	4.78	5.11				
		s.e.	± 0.0999									
II (*Pueraria phaseoloides*)	Leaf	< 5	2 53	2.46	3.07	3.42	3 75	3.78	2.72	3.02	3 09	± 0.0606
		6	3.42	3.53	3.86	3 86	3 34	3.50	3 70	3.64	3.61	
		7	3.74	3.37	4.31	4.42	3.56	3.65	3.17	3.20	3.68	
		Mean	3.23	3.12	3.75	3 90	3.55	3.64	3.20	3.29		
		s.e.	± 0.099									
	Stem	< 5	0.95	1 08	1.05	1 24	1.47	1.49	0.96	1 14	1 17	± 0.0309
		6	1.27	1.27	1.53	1.61	1.30	1.48	1.55	1 46	1.43	
		7	1.55	1 29	1.73	1.82	1.44	1.39	1.27	1.16	1.46	
		Mean	1.26	1.21	1.44	1.56	1.40	1.45	1.26	1.25		
		s.e	± 0.0504									
	Nodules	< 5	3.47	4.22	3.94	4.03	4.40	4.53	3.47	4.00	4.01	± 0.1019
		6	3.79	4.04	4.46	4.05	4.59	4.33	4.74	4.68	4.34	
		7	3.57	3 82	4.55	4 65	4.77	4.47	4 09	4.52	4.31	
		Mean	3.61	4.03	4.32	4.24	4.59	4.44	4.10	4 40		
		s.e.	± 0.1662									

Soil Series columns: Kedah, Rengam, Selangor, Malacca; sub-columns are Molybdate level 0 and 1.

TABLE 6. MANGANESE IN LEAF, STEM AND NODULES, P.P.M.

Experiment	Material	Soil pH	Soil Series								Mean	s.e.
			Kedah		Rengam		Selangor		Malacca			
			Molybdate level									
			0	1	0	1	0	1	0	1		
I (*Centrosema pubescens*)	Leaf and stem	< 5	63	47	95	81	206	185			113	
		6	16	9	14	15	83	74			35	± 2.408
		7	13	7	15	17	77	82			35	
		Mean	31	21	41	38	122	114				
		s.e.	± 3.405									
II (*Pueraria phaseoloides*)	Leaf	< 5	87	68	70	68	87	81	119	70	81	
		6	72	69	42	48	79	90	111	107	77	± 3.057
		7	37	41	28	24	56	45	55	44	41	
		Mean	65	59	47	47	74	72	95	74		
		s.e	± 4.992									
	Stem	< 5	525	307	297	264	489	494	1438	1176	624	
		6	60	42	18	23	76	109	138	163	79	*
		7	15	17	12	10	28	23	27	22	19	
		Mean	200	122	109	99	198	209	534	454		
		s.e.	*									
	Nodules	< 5	13	16	15	26	22	18	50	45	26	
		6	16	11	7	18	19	17	26	31	18	± 2.717
		7	13	9	16	16	11	17	64	28	22	
		Mean	14	12	13	20	17	17	47	35		
		s.e.	± 4.436									

* s.e. not calculated because of large treatment variations

TABLE 7. PERCENTAGE MAGNESIUM IN LEAF, STEM AND NODULES.

Experiment	Material	Soil pH	Soil Series								Mean	s.e.
			Kedah		Rengam		Selangor		Malacca			
			Molybdate level									
			0	*1*	*0*	*1*	*0*	*1*	*0*	*1*		
I (*Centrosema pubescens*)	Leaf and stem	< 5	0.16	0.14	0.12	0.12	0.21	0.21			0.16	
		6	0.11	0.12	0.14	0.15	0.23	0.23			0.16	±0.0044
		7	0.10	0.12	0.14	0.15	0.25	0.23			0.17	
		Mean	0.12	0.13	0.13	0.14	0.23	0.23				
		s.e.	± 0.0062									
II (*Pueraria phaseoloides*)	Leaf	< 5	0.43	0.34	0.40	0.37	0.37	0.36	0.45	0.33	0.38	
		6	0.29	0.34	0.33	0.32	0.30	0.30	0.29	0.29	0.31	±0.00572
		7	0.30	0.32	0.33	0.33	0.31	0.31	0.33	0.34	0.32	
		Mean	0.34	0.33	0.35	0.34	0.33	0.32	0.36	0.32		
		s.e.	± 0.0107									
	Stem	< 5	0.23	0.19	0.21	0.24	0.20	0.20	0.24	0.19	0.21	
		6	0.22	0.19	0.19	0.19	0.15	0.16	0.17	0.15	0.18	±0.00397
		7	0.22	0.22	0.21	0.22	0.18	0.19	0.20	0.21	0.21	
		Mean	0.22	0.20	0.20	0.22	0.18	0.18	0.20	0.18		
		s.e.	± 0.0065									
	Nodules	< 5	0.20	0.19	0.24	0.21	0.30	0.29	0.21	0.24	0.24	
		6	0.22	0.25	0.25	0.21	0.35	0.29	0.41	0.33	0.29	±0.0149
		7	0.28	0.22	0.32	0.35	0.31	0.28	0.28	0.24	0.29	
		Mean	0.23	0.22	0.27	0.26	0.32	0.29	0.30	0.27		
		s.e.	± 0.0243									